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Secondary neutrons issue in proton radiotherapy—a brief report

Mohammad Rafiqul Islam

Lawrence Cancer Center, 330 Arkansas Street, KS 66044, USA.

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Scientific Note

Abstract

Secondary neutrons are unwanted byproduct in proton radiotherapy. Exposure due to secondary neutrons in proton radiotherapy could cause a significant risk for developing a secondary cancer later in the patient lifetime. The level of exposure due to secondary neutrons primarily depends on the type of beam delivery system used to deliver the primary proton dose. Although the patient body can produce significant neutrons but since these neutron are created inside the human body, their exposure is unavoidable. This report briefly discusses the type of beam delivery systems currently in use in proton radiotherapy, a relative comparison of neutron exposure in each case, and the importance of neutron study in proton radiotherapy.

Keywords: Proton therapy; Secondary neutrons; Secondary Cancer; Beam Delivery

Scientific Note

In 1946, Robert Wilson first suggested that the beams of energetic protons can be employed in the treatment of cancer.[1] This is because the relatively larger mass of proton compared to x-rays and electrons would cause less scattering, and the greater energy deposition of protons at the end of their range would allow highly localized irradiation. The property of Bragg peak enabled proton therapy to be a superior modality in certain cases compared to conventional MV X-ray (photon) radiotherapy.[2] However, the conformity of dose is achieved by passing proton beams through various materials inside the beam delivery system and this result in the production of secondary neutrons. The basic mechanism of neutron production is the non-elastic interactions of energetic protons with atomic nuclei of the interacting media.[3-4] The energy of the secondary neutrons depends on the energy of the incident protons and can contain sufficient range to reach the patient and deposit dose outside the treatment volume. This undesired dose from secondary neutrons could pose a significant risk factor for developing a secondary cancer later in the life time since neutrons have higher relative biological effectiveness (RBE).[5-6] Although the association between secondary cancer and neutrons dose is not yet well understood [7], the study of secondary neutrons is important for the overall quality of treatment.

Corresponding author: Mohammad Rafiqul Islam, PhD; Lawrence Cancer Center, 330 Arkansas Street, KS 66044, USA.
Email: rafiqphy@gmail.com

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Currently, there are two types of beam delivery systems available: passive scattering and active scanning. In general, passive scattering employs scattering material in the beam path for dose conformity while active scanning employs scanning magnets to irradiate the tumor volume. Active scanning systems are also classified into two categories [8]: a) pencil beam scanning, and b) uniform scanning. The basic difference between these two categories is that the pencil beam scanning system may not require any beam shaping components while uniform scanning system requires beam shaping components.[9] In addition, pencil beam scanning is capable of delivering a beam of variable intensity during scanning, while uniform scanning employs a beam of uniform intensity.[8, 10, 11] In general, the passive scattering system uses more beam shaping components than that of active scanning system and presumably produces more secondary neutrons.

For the understanding of secondary radiation in proton radiotherapy, a numerous studies have been performed and is considered to be a very active area of research. Both measurements and numerical simulations have been conducted to determine the secondary radiation for a greater number of scenarios to replicate the real life problem. A comparison of available neutron study from various proton facilities help to see the latest standing of this issue. It is to be noted that the comparison of neutron dose among facilities are not exact as the treatment condition, beam shaping components vary from facility to facility.

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In 2002, Yan *et al.*[12] reported 4.5 mSv/Gy of neutron dose for passive scattering system @160 MeV proton beam for Harvard Cyclotron Laboratory (HCL), 50 cm off-axis to the primary beam. Using a pencil beam scanning approach, Schneider *et al.*[13] reported 0.12 mSv/Gy for 177 MeV proton beam at Paul Scherrer Institute (PSI) Proton Therapy Facility, Switzerland. Zheng *et al.*[8] conducted a study for a uniform scanning system at ProCure Proton Therapy Center, Oklahoma, USA. For a 78 MeV proton beam, Zheng *et al.* reported 0.35 mSv/Gy at 50 cm off-axis to the primary beam.[8] Most recently, Islam *et al.*[14] conducted a study for the uniform scanning system at ProCure Proton Therapy Center, Oklahoma and also compared the neutron dose among different facilities. According to Islam *et al.*[14], neutron dose ranged from 0.3 to 38 mSv/Gy for the proton energy ranges from 78 to 226 MeV. This data also reveals that the dose from the uniform scanning system is comparable with passive scattering system but greater than that of pencil beam scanning system. The overall study for different scanning mechanisms demonstrates that the neutron dose ranges from 0.1 to about 50 mSv/Gy for therapeutic proton energies. It is to be noted that the uncertainty involved in neutron measurement is generally high, and different measurement techniques can also lead to a greater variation in the reported dose.

In summary, proton radiotherapy is becoming increasingly important as an effective form of radiotherapy[2, 15] but the advantage of proton radiotherapy could be suffered due to the presence of secondary neutrons. It is true that the measurement of dose and dose equivalent due to neutrons is not straightforward as the neutrons interaction (cross section) with common detecting material used in radiation detector is negligible. But the determination of neutron dose due to primary proton beam is important as neutrons have higher RBE. Furthermore, the current treatment planning systems in proton therapy do not include the dose contribution due to the secondary neutrons. In this context, the secondary neutrons produced in proton treatment facility should be assessed and minimized as much as possible. Additionally, the neutron study can help in improving the available radiation risk modeling, which may assist the physicians to take informed decisions.

Conflict of interest

The author declares that he has no conflicts of interest. The author alone is responsible for the content and writing of the paper.

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